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THE ECONOMIC IMPACT OF INVASIVE SPECIES TO WILDLIFE SERVICES' COOPERATORS

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Abstract: On February 3, 1999, the president of the United States signed an Executive Order 13112 on invasive species. Each federal agency was directed to detect and respond rapidly to control populations of invasive species, monitor invasive species populations, provide for restoration of native species and habitat conditions, conduct research on invasive species and develop technologies to prevent their introduction, and promote public education on invasive species and the means to address them. The United States Department of Agriculture's Wildlife Services Program fulfills a federal responsibility for helping solve problems which occur when human activity and wildlife, including invasive species, are in conflict with one another. This is accomplished through the recommendation and/or implementation of integrated pest management strategies (IPM). IPM strategies often involve both technical assistance and direct management. This paper provides a summary of 8 years of Wildlife Services involvement in the resolution of invasive species conflicts with agricultural resources, property, human health and safety, and natural resources.

Key words: black rats, brown treesnakes, cats, dogs, economics, exotics, feral, hogs, invasive species, Norway rats, nutria, pigeons, starlings, wildlife damage

Wildlife and plants have been introduced outside of their native range for a variety of reasons, including: accident, nostalgia, aesthetics, companionship, food, recreation, protection, clothing, biotic enhancement, pest control, and utility. Although not all introductions have resulted in established populations or have had negative impacts, some species' introductions have resulted in established populations and have had impacts on native ecosystems and human activities. Native wildlife species often suffer as a consequence of their encounters with invasive species. Consequences may include: direct competition for resources, displacement from native habitat, exposure to exotic diseases, predation, and general habitat degradation.

Today, in the United States there are more than 50,000 invasive species and the number continues to increase (Pimental et al. 1999). The U.S. Congress, Office of Technology Assessment (1993) stated that a conservative estimate of damage caused by invasive species within the United States amounts to hundreds of millions of dollars on an annual basis. In high-impact years, losses may be in the billions of dollars. The study also reported that 79 invasive species accounted for approximately US$97 billion in damages from 1906 to 1991 (U.S. Congress, Office of Technology Assessment 1993). A more recent estimate by Pimental et al. (1999) estimated the annual cost of all invasive species within the United States to be more than US$138 billion.

During the 1990s, the federal government saw a need to increase its authority to manage invasive species. The Nonindigenous Aquatic Nuisance Prevention and Control Act was passed on November 29, 1990, and was subsequently amended by the National Invasive Species Act of 1996. In general, the act provided for the development and implementation of a program for the waters of the United States to prevent introduction and dispersal of aquatic nuisance species; to monitor, control and study such species; and to disseminate related information. Section 1209 of the act required the development of an environmentally sound program in coordination with regional, territorial, state and local entities to control the brown treesnake (*Boiga irregularis*) in Guam and other areas where the species is established outside of its historic range.

On February 3, 1999, President Clinton signed Executive Order 13112 enhancing and coordinating federal activities to control and minimize the economic, ecological, and human health impacts caused by invasive species. The executive order also established a National Invasive Species Council to oversee a management plan detailing the goals and objectives of the efforts of the involved federal agencies. This executive order provides new impetus and importance to the basic work performed by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service, i.e., preventing the introduction and establishment in the United States of pests and diseases that could threaten the country's resources, and managing those species already established.

The U.S. Department of Agriculture (USDA) has been protecting the United States from invasive species since the late 1800s and early 1900s. "Protecting American agriculture" is the basic charge of the USDA's Animal and Plant Health Inspection Service (APHIS). APHIS provides leadership in ensuring the health and care of animals and plants. Current APHIS programs include Plant Protection and Quarantine (preventing, controlling or eliminating plant pests), International Services (preventing invasive species from leaving their countries of origin), Veterinary Services (preventing,

controlling, or eliminating domestic animal diseases), and Wildlife Services (managing wildlife damage).

The mission of the Wildlife Services (WS) Program is to provide federal leadership in managing wildlife damage to protect agricultural resources, property, and natural resources and to safeguard public health and safety. Relying on an integrated approach to resolve wildlife conflicts, WS employs wildlife damage prevention and control methods which are effective, economical, and environmentally sound. WS assistance is provided upon request to federal, state, and local government agencies; private organizations and corporations; and individuals.

WS provides operational assistance through 2 avenues, technical assistance and direct damage management programs. WS' programs are used to address the increasing number of wildlife conflicts throughout the country. Technical assistance includes the dissemination of information and materials to groups or individuals for their use in resolving wildlife damage conflicts. Information is shared through training workshops, demonstrations, and verbal or written communication and may include the loan of damage abatement equipment. WS' direct damage management programs are usually cooperatively funded, cost-shared projects which enable WS personnel to address wildlife damage problems directly. This paper is a compilation of information acquired during WS' involvement with invasive species damage management during Fiscal Years (FY) 1990 through 1997.

METHODS

WS employees use a Management Information System (MIS) to collect thorough and accurate information on program activities and accomplishments. Some of the objectives of the MIS system are to: 1) record program effort, 2) assist in the analysis of program results, 3) quantify the amount and value of resources damaged by wildlife, 4) help determine program effectiveness, and 5) document wildlife damage management methods recommended and used.

The core of MIS data is tied to the location where wildlife conflicts happen in terms of proximate land site locations. All operational work is tracked by specific land properties. Technical assistance work also may be tracked by specific property if desired, but technical assistance is most commonly tracked by locations of city or county designations. An Agreement for Control of Animal Damage is required prior to initiating work on any property. Data on management efforts conducted are recorded each time a property is worked. The data include items such as: time spent, damage reported or verified, species taken, methods used, and equipment and/or chemicals placed. Technical assistance provided by WS employees is captured by recording species and damage data, type of assistance provided, and recommendations made.

Each fiscal year, MIS data is summarized at the state level and sent to WS Operational Support Staff in Riverdale, Maryland. After several error checks, the information is summarized in 11 annual tables and released to the public.

RESULTS AND DISCUSSION

The data compiled through the MIS showed that invasive wildlife species impacted every state and all US territories. WS received requests to conduct operational activities on a minimum of 44 vertebrate invasive species, including 17 species of invasive mammals, 25 species of invasive birds, and 2 species of invasive reptiles (Table 1). Invasive birds were responsible for damage in every state, the District of Columbia, Guam, Puerto Rico, and the Virgin Islands (Fig. 1). Assistance for invasive mammals occurred in the District of Columbia and every state and territory except Delaware and Con-

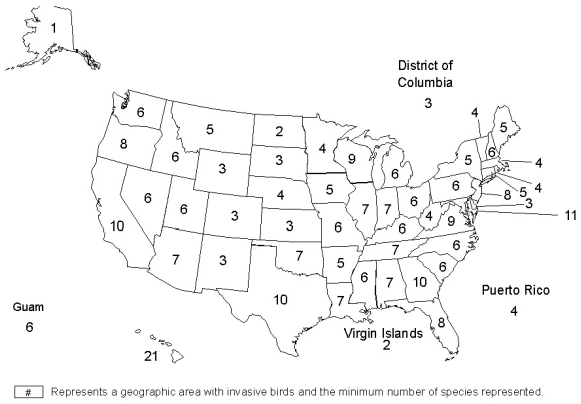

Fig. 1. Geographic location where assistance was requested for damage caused by invasive birds, including the minimal number of invasive bird species, from Fiscal Years 1990 through 1997.

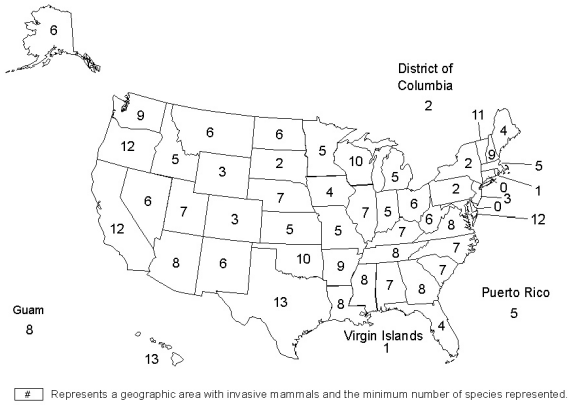

Fig. 2. Geographic location where assistance was requested for damage caused by invasive mammals, including the minimal number of invasive mammal species, from Fiscal Years 1990 through 1997.

Table 1. Geographic locations where assistance was requested to alleviate damage caused by vertebrate wildlife species during Fiscal Years 1990 to 1997

Common name	Scientific name	States where assistance was provided
Birds		
Bulbul, Red-Vented	*Pycnonotus cafer*	HI
Bulbul, Red-Whiskered	*Pycnonotus jocosus*	HI
Cardinals, Red-Crested	*Paroaria coronata*	HI, TX
Chickens, Feral	*Gallus gallus*	MD
Dove, Spotted	*Streptopelia chinensis*	HI
Dove, Zebra	*Geopelia striata*	HI
Drongos, Black	*Dicrurus macrocercus*	GU
Ducks, Feral		AL, AR, AZ, CA, FL, GA, HI, IA, ID, IN, KY, LA, MD, ME, MI, MO, MS, NC, NH, NJ, NV, NY, OK, OR, PA, PR, SC, TN, TX, UT, VA, WA, WI
Egrets, Cattle	*Bubulcus ibis*	AL, AR, AZ, CA, FL, GA, GU, HI, ID, IA, MD, MO, MS, OK, PR, TX, VA, VI, WI,
Exotic Birds (Other)		AL, AR, AZ, CA, FL, GA, GU, HI, IL, LA, MD, MI, NM, NV, OK, OR, RI, SC, TN, TX, UT, VA, WI
Francolin, Black	*Francolinus francolinus*	GU, HI
Francolin, Erckel's	*Francolinus erckelii*	HI
Francolin, Gray	*Francolinus pondicerianus*	HI
Geese, Feral		AZ, CA, CT, FL, GA, IL, IN, KY, LA, MD, MO, MS, MT, NC, NE, NH, NJ, NV, OH, OK, OR, PA, SC, TN, TX, VA, WA, WI, WV
Junglefowl, Red	*Gallus gallus*	HI
Mannikin, Chestnut	*Lonchura atricapilla*	HI
Mannikin, Nutmeg	*Lonchura punctulata*	HI
Mynas (All)		HI
Parakeets, Monk	*Myiopsitta monachus*	CA, CT, DE, FL, GA, IL, IN, LA, MA, MD, MN, NJ, OH, OR PR, TX, VA
Pheasant, Ring-Necked	*Phasianus colchicus*	CA, HI, ID, MD, MT, ND, NE, NJ, OR, TX, UT, VT, WA, WI
Pigeons, Feral (Rock Dove)	*Columba livia*	AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, GU, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, NH, NJ, NV, NY, OH, OK, OR, PA, PR, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
Sparrows, Eurasian Tree	*Passer montanus*	GA, GU
Sparrows, House/English	*Passer domesticus*	AL, AR, AZ, CA, CO, CT, DC, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
Sparrows, Java	*Padda oryzivora*	HI
Starlings, European	*Sturnus vulgaris*	AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
Swan, Mute	*Cygnus olor*	CA, GA, HI, IL, IN, KY, MD, ME, MI, NC, NH, NJ, NY, OH, PA, RI, TN, VA, WI
Mammals		
Burros, Feral	*Equus asinus*	CA
Cats, Feral/Free Ranging	*Felis catus*	AK, AL, AR, AZ, CA, CO, FL, GA, GU, HI, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PR, SC, TN, TX, UT, VA, VT, WA, WI, WV, WY
Cattle, Feral	*Bos taurus*	HI, MD, NV, VT, WI

Table 1. Continued

Common name	Scientific name	States where assistance was provided
Deer (Other)	*Cervidae*	AZ, CA, GA, GU, HI, IL, KY, MD, OR, TX, VT, WA, WY
Dogs, Feral/Free Ranging & Hybrid	*Canis* spp.	AK, AL, AR, AZ, CA, CO, FL, GA, GU, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, OH, OK, OR, PA, PR, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
Ferrets, European	*Mustela furo*	CA, MD, NE, NH, OR, TN, TX, UT, VA, VT, WI
Foxes, Arctic	*Alopes lagopus*	AK
Goats, Feral	*Capra hircus*	CA, HI, NC, OK, TX
Hogs, Feral	*Sus scrofa*	AL, AR, AZ, CA, FL, GA, GU, HI, KS, LA, MO, MS, NC, ND, NE, NH, NM, OH, OK, OR, SC, TN, TX, VA, VT, WI
Horses, Feral	*Equus caballus*	CA, MD, OR, VT
Mammals, Exotic z-(Other)		AR, MD, MS, MT, NH, OK, PR, TX, VT, WI
Mice, House	*Mus musculus*	AL, AR, AZ, CA, DC, GA, GU, HI, IA, ID, IL, IN, KS, KY, MA, MD, ME, MI, MN, MS, MT, NC, ND, NE, NH, NV, OH, OK, OR, SC, TN, TX, UT, VA, VT, WA, WI, WV
Mice/Rats (Mixed)		AL, AR, AZ, GA, GU, HI, IL, IN, KY, LA, MD, MI, MN, MO, MS, MT, NH, NM, NV, OK, OR, PA, PR, SC, TN, TX, UT, WA, WI
Mongooses, Indian	*Herpestes nyula*	HI, PR, VI
Nutrias	*Myocastor coypus*	AL, AR, LA, MD, MS, NC, OK, OR, TX, VA, WA
Rabbits, Feral	*Oryctolagus cuniculus*	AK, CA, CO, HI, ID, LA, MA, MD, MT, ND, NH, NV, OH, OR, TX, VT, WA, WV
Rats, Black (Roof)	*Rattus rattus*	AK, AR, AZ, CA, FL, GA, GU, HI, IA, IL, LA, NE, NM, OK, OR, SC, TN, TX, UT, VA, WA, WI, WV
Rats, Norway	*Rattus norvegicus*	AK, AL, AR, AZ, CA, DC, GA, GU, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV
Rats, Polynesian	*Rattus exulans*	HI, KY
Amphibians & Reptiles		
Lizards, Monitor	*Varanus indicus*	GU
Reptiles, Exotic		AZ , GU, LA, MD, ME, MN, MO, OK, PR, TX, UT, WI
Snakes, Brown Tree	*Boiga irregularis*	GU, HI

necticut (Fig. 2). Assistance to alleviate damage caused by invasive reptiles occurred in 11 states, Guam, and Puerto Rico (Fig. 3).

Every geographic area (states, District of Columbia, and U.S. territories) had at least 3 species of invasive wildlife. Invasive birds ranged from 1 (Alaska) to 21 (Hawaii) species with an average of 6 and a median of 6. Invasive mammals ranged from 0 (Delaware, Connecticut) to 13 (Hawaii, Texas) species with an average of 7 and a median of 6. Invasive reptiles ranged from 0 to 3 (Guam) species with an average of 2 and a median of 1.

More than 45 invasive vertebrate species were reported to and verified by WS personnel as being responsible for damages to natural resources, human health and safety, property, and agriculture. The number is conservative because many of the invasive

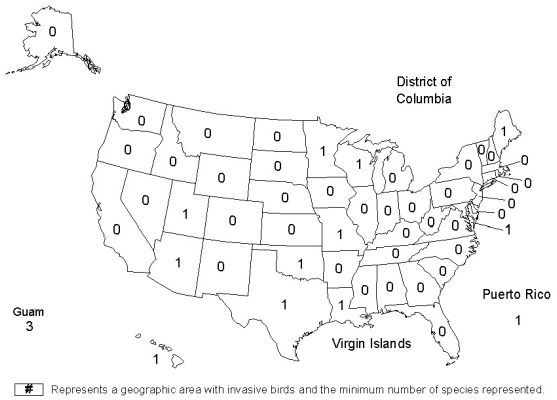

Fig. 3. Geographic location where assistance was requested for damage caused by invasive reptiles, including the minimal number of invasive reptile species, from Fiscal Years 1990 through 1997.

species are grouped into general categories such as exotic birds, exotic mammals, exotic reptiles, mixed mice and rats, other deer. This designation does not include white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*), multi-species designations, and mynas. WS provides operational support for a multitude of additional invasive species, such as invasive red fox (*Vulpes fulva*) in California, that are not addressed in this paper due to the special circumstances of the management situations. In the Dakotas, WS also removes invasive hybrid cattails (*Typha* spp.) which provide roosting habitat for native blackbirds causing damage to crops.

The public often asks WS to account for resource losses, damages attributable to individual species, and funding spent on individual methods for managing wildlife. WS does not track its funding by species causing damage or by method used. Instead WS tracks its expenditures by resource category protected. Monetary damage attributed to invasive wildlife species and reported to WS is minuscule when compared to the overall damages caused by these species. Much of the damage, such as losses of threatened and endangered species (e.g., extinction of birds on Guam caused by brown treesnakes), damage to natural areas (e.g., overbrowsing of vegetation and habitat degradation), and threats to human health (e.g., zoonoses), are not readily quantified. Most of the aforementioned items are irreplaceable and only have a monetary value attached to them when there is a lawsuit over the loss of these resources. This monetary value varies immensely and is determined by whatever current knowledge exists among judges and juries. Bioeconomic analyses are an option for estimating the value of lost resources, but such model estimates often are unknown or unavailable to traditionally trained wildlife managers. The following synopsis reports damage estimates for cases of conflicts where WS assistance was requested. We follow these reports with a perspective of WS involvement relative to damage estimates on a national scale.

Invasive Birds

Of the more than 1,000 species of birds in the United States, 97 species are considered invasive and 5% of the invasive birds, including chickens, are considered beneficial (Temple 1992). WS had requests for assistance to manage damage caused by 25 invasive bird species, which equates to 26% of the invasive birds within the United States, including beneficial invasive species such as chickens. The cumulative effect of damages reported to WS caused by invasive birds amounted to greater than US$28 million over an 8-year period.

More states and territories requested assistance for controlling invasive bird species than for the other 2 categories of vertebrates (i.e., mammals; reptiles and amphibians). In tabulating assistance requests, Wildlife Services did not categorize all genera and species of birds separately. Due to the low frequency of occurrence of some species, they were grouped into the general category of "exotic birds." Species attributed to the "exotic birds" category occurred in 23 states and Guam (Table 1). Species of mynas were grouped into the category of mynas (all). Requests for assistance with myna damage only occurred in Hawaii (Table 1).

Among invasive bird species, federal relief assistance requested by states and territories most commonly involved feral pigeons (*Columba livia*, n = 50) European starlings (*Sturnus vulgaris*, n = 49), and house sparrows (*Passer domesticus*, n = 48) (Table 1). About half the states and territories requested assistance in controlling invasive ducks (n = 28) and geese (n = 29), and about a third of the states and territories requested assistance to manage problems associated with mute swans (*Cygnus olor*, n = 19), cattle egrets (*Bubulcus ibis*, n = 22), monk parakeets (*Myiopsitta monachus*, n = 17), and ring-necked pheasants (*Phasianus colchicus*, n = 14). The remaining requests for assistance largely reflected regional or local problems. Requests for assistance for 13 invasive species came from a single state or territory, with 11 of those species occurring only in Hawaii. Three invasive avian species were represented by only 2 geographical regions (state, District of Columbia, or U.S. territory).

Of the conflicts reported to WS, invasive birds accounted for < US$10,000 in damage to natural resources throughout the Fiscal Years (FY) 1990-1997 (Fig. 4). In FY 1990 and 1996, no natural resource damages were reported, and FY 1992 only had US$1 in natural resource damage reported. Losses caused by invasive birds associated with human health and safety issues had a low of US$22,700 in FY 1991 and a high of US$231,000 in FY 1994. Damages to agriculture caused by invasive birds had a low in FY 1990 of US$278,417, but the amount more than doubled for FY 1991 and peaked in FY 1995 at US$1,502,488.

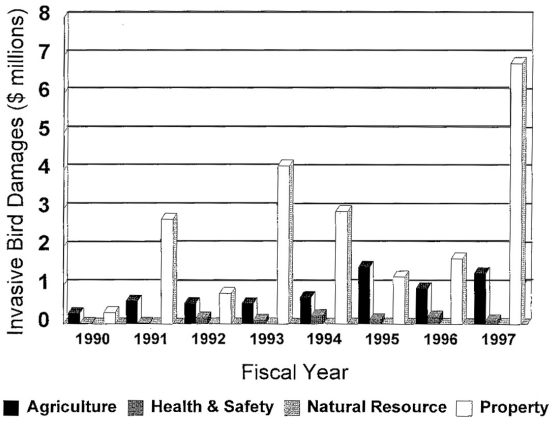

Fig. 4. The amount of invasive bird-caused damages reported to Wildlife Services during the period of Fiscal Years 1990-1997.

Invasive birds had their greatest impact on property. They had a low in FY 1990 of US$309,131 and peaked in FY 1997 at US$6,827,775 in damages to property. The total monetary damage attributable to invasive bird species and reported to WS by those requesting relief amounted to US$28,194,557 over the 8-year period, with a range of US$615,348 to US$8,262,498, an average of US$3,524,320, and a median of US$3,128,440 per year. Two species of invasive birds, the European starling (US$13.5 million) and common pigeon (US$12.7 million), accounted for 93% of the approximately US$28 million in invasive bird damage reported to WS throughout FY 1990-1997.

Invasive European starlings were reported to WS as causing damage in every state except North Dakota and Alaska. The reason invasive European starlings were not recorded as causing damage in some geographic areas may be due to their migratory patterns. In the Great Plains, starlings often migrate and roost with blackbirds. Consequently, invasive European starlings may not have been accounted for in every geographic location due to their mixing with blackbirds. When such is the case, starlings are tracked within the MIS under the general code of mixed blackbird species. Over the 8-year period, invasive European starlings accounted for > US$13.5 million in damage to all resources, ranging from US$235,067 to US$4,137,119, with an average of US$1,694,170 and a median of US$1,457,014 per year. Pimental et al. (1999) estimated that yearly starling damage to agriculture was US$800 million in damages per year to agriculture crops based on a figure of US$5/ha. The WS-reported damage, attributable to starlings, comprised only 1.7% of this total. If WS had summed up the invasive European starling crop damages alone, the figure would be considerably smaller when considering that the majority of starling damage is to property. This does not account for the 25 diseases that may be transmitted to humans (Weber 1979) where a monetary value can not be readily derived. It is also difficult to derive a monetary value for environmental damage caused by invasive starlings, such as displacing native birds from nesting cavities.

Robbins (1995) stated that the single, most serious pest bird in the United States is the common pigeon, an invasive species. Pigeons were reported to WS as being responsible for damages in every state and territory except the Virgin Islands. Pigeons cause damage to property and agriculture, and are a threat to human health and safety. Pigeons are a reservoir and vector for more than 50 human and livestock diseases including ornithosis, histoplasmosis, and encephalitis (Weber 1979, Long 1981). Haag-Wackernagel (1995) estimated that management costs associated with pigeon control are US$9 per bird per year. Invasive pigeon damages reported to WS ranged from US$198,209 to US$6,412,725 with an average of US$1,590,730 and a median of US$804,481 per year. The total damage attributable to invasive pigeons represented 1.1% and 0.1%, respectively of the amount of yearly damages (US$1.1 billion) estimated by Pimental et al. (1999).

Invasive Mammals

Layne (1997) reported that there are 20 species of invasive mammals in the United States, but Trawick (1995) stated that there are at least 71 species of invasive ungulates in Texas alone. WS figures provide data that address 17 invasive mammal species. The discrepancies in species numbers is largely attributable to the practice of combining species into general exotic mammal and 'other deer' categories. The number of invasive mammal species in the United States has grown exponentially over the past 30 years. One reason for this increase has been escape of species held on game farms, hunting preserves, private collections, and zoos. When invasive wildlife escapes, WS is often called upon to remedy the problem.

The most frequent requests from states and territories for WS assistance was for feral dogs (*Canis familiaris*, n = 47), feral cats (*Felis domesticus*, n = 46), Norway rats (*Rattus norvegicus*, n = 45), house mice (*Mus musculus*, n =38), and mixed invasive mice and rat problems (n = 29). About half of the states and territories requested assistance from WS for managing invasive hog (*Sus scrofa*, n = 26) and black rat (*Rattus rattus*, n =23) problems. A third of the states and territories requested assistance for controlling feral rabbits (*Oryctolgaus cuniculus*, n = 18). The remainder of the 11 invasive species receiving WS attention reflected more regional or local problems with invasive mammals (Table 1).

The cumulative effect of damage caused by invasive mammals amounted to > US$14 million over an 8-year period. A small fraction of this total was reported to have impacted natural resources i.e., <US$6,000 from

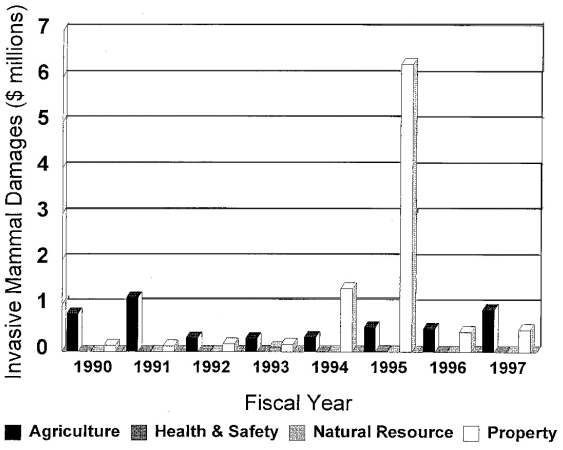

Fig. 5. The amount of invasive mammal-caused damages reported to Wildlife Services during the period of Fiscal Years 1990-1997.

FY 1990-1997, exclusive of FY1993 (Fig. 5). In FY 1990, invasive mammals only had US$24 in natural resource damages reported and reached a peak in FY 1993 at US$108,172. Polynesian rats (*Rattus exulans*) in Hawaii accounted for US$100,000 of the aforementioned natural resource losses to colonial sea birds. Losses caused by invasive mammals associated with human health and safety issues had a low of US$0 in FY 1992 and a high of US$25,860 in FY 1995. Agriculture damages caused by invasive mammals peaked in FY 1991 with US$1,175,738 and dropped to a low of US$296,799 in FY 1993, but by FY 1997, agricultural damages attributed to invasive mammals had once again climbed and reached US$935,279. Invasive mammals had their greatest impact on property. They had a low in FY 1991 of US$121,805 and peaked in FY 1995 with US$6,293,593 of damages to property. The total invasive mammal damages to all resources amounted to US$14,350,519 over the 8-year period with a range of US$574,448 to US$6,859,559, an average of US$1,793,814 and a median of US$1,141,426 per year.

The most frequent request for assistance among states and territories was for relief from invasive dogs. Invasive dogs accounted for 20% or US$2,865,284 of the total damage reported to WS and ranged from US$161,352 to US$746,994 with an average of US$358,160 and a median of US$283,696 per year. The National Agricultural Statistics Service (1995, 1996) reported that invasive dogs cause an estimated US$6.95 million in direct losses to the cattle industry and US$2.2 million in direct losses to the sheep industry per year. Losses to goats attributable to dogs amount to US$602,800. Pimental et al. (1999) stated that an economic impact of US$10 million to livestock is a conservative estimate. Additionally, invasive dogs (feral and captive) bite an estimated 4.7 million individuals each year (Sacks et al. 1990). The economic costs attributed to dog-bites is US$165 million/year in direct costs and US$250 million/year in indirect costs (Pimental et al. 1999, Quinlan and Sacks 1999). In addition, invasive dogs cause an average of 23 fatalities per 2-year period with up to 80% of those being children (Centers for Disease Control and Prevention 1997).

There are an estimated 30 million invasive (feral) cats (Luoma 1997) and an estimated 63 million invasive (captive) cats (Nassar and Mosier 1991) in the continental United States. WS received requests for assistance from all geographic areas except Delaware, District of Columbia, Connecticut, Rhode Island, Iowa, South Dakota, and the Virgin Islands. Despite the widespread requests for assistance, cats accounted for only US$54,192 of estimated damage over the 8-year period. Data from the MIS annual tables accounted for damage to agriculture, property, human health and safety, and natural resources. However, estimates of the impact of cats on natural resources such as wild birds are most likely severely underreported within the MIS program. Pimental et al. (1999) placed an estimated value of US$30 per bird, estimated cats killed 465 million birds per year, and estimated the value of this lost resource at US$14 billion.

There are an estimated 250 million invasive rats associated with homes and related areas and 1.4 billion associated with chicken farms in the United States (Pimental et al. 1999). WS data shows that rats caused damage in every state and territory except the Virgin Islands, Connecticut, and Colorado. WS estimates that the monetary value placed on damage caused by invasive black rats was 12.6% of the total reported to WS, or US$1,806,787. Damage ranged from US$26,271 to US$1,428,881 and averaged US$225,848 with a median of US$49,445 per year. Additionally, damage attributable to invasive Norway rats and Polynesian rats amounted to US$294,010 (2%) and US$110,000 (1%), respectively. The total damage attributable to rats and estimated by WS was US$2,210,797 with black rats accounting for 82% of the damage reported. The Animal Damage Control Act of 1931 precludes WS from conducting operational work on urban rodents. The estimate by Pimental et al. (1999) covered all sectors of the United States, and they conservatively estimated that invasive rats caused US$19 billion damage per year.

Pimental et al. (1999) estimated that there are 4 million invasive swine in the United States, but Muller et al. (2000) estimated that there are 3 million invasive swine in Texas alone. Regardless, invasive swine are abundant and cause considerable damage. Data from 1988 showed that invasive swine were located in 16 states (U.S. Department of Agriculture, Animal and Plant Health Inspection Service 1991). By 1999, Muller et al. (2000) reported that invasive swine had established populations in 24 states. Data in the MIS system from FY 1990 to 1997 showed invasive swine in 5 additional states (New Hampshire, Vermont, Nebraska, North Dakota, and Oregon) and 1 territory (Guam) not accounted for by Muller et al. (1999) data. Invasive swine continue to expand their range and are now located in 30 states and 1 territory. Invasive swine ranked fourth in the WS estimates for the amount of damage reported, totaling US$1,200,103 (8%) with a range of US$15,977 to US$296,814, an average of US$150,012 and a median of US$150,459 per year. The total damages reported to WS over the 8-year period were US$1.2 million. In addition to direct damage to natural resources, agriculture, and property, invasive swine are known to carry 45 different parasites and infectious diseases (Belden 1993). Damage caused by invasive swine throughout the United States were estimated at US$800 million to agriculture and the environment (Pimental et al. 1999). However, given the population trends it is arguable that this value could be even higher.

Texas has the most widespread and abundant populations of invasive ungulates within the United States (Teer et al. 1993). Invasive populations of ungulates in Texas have grown from approximately 14,000 animals and 13 species in 1963 to more than 164,000 animals and 67 species in 1988 (Mungall and Sheffield 1994). A 1994 survey estimated that there were about 195,000 invasive mammals representing 71 species (Traweek 1995), but Demarais et al. (1998) stated that the population numbers should be closer to 258,000.

Despite the smaller number of states and territories requesting assistance for control of invasive nutria (n = 11), this species was responsible for 60% or US$8.6 million of the > US$14 million in damages to resources with US$6,209,293 or 43% in FY 1995 alone. Damages caused by invasive nutria ranged from US$19,855 to US$6.2 million with an average of US$1,076,112 and a median of US$194,286 per year. Bergman and Mastrangelo (In Press) reported nutria as a pest species in 15 states, of which 11 states had WS operational programs resolving nutria complaints. Damage to all resource types associated with the aforementioned nutria complaints ranged from US$1.9 million in 1990 to > US$8.8 million in 1997, with a peak of US$6.2 million in 1995. The large increase in FY 1995 can be attributed to a US$6 million loss to sugarcane fields. The Blackwater National Wildlife Refuge (BNWR) loses 500-1000 acres of wetland habitat per year from invasive nutria damage and several times that amount over the entire BNWR/Fishing Bay estuary (G. Carowan, U.S. Fish Wildlife Service 2000, personal communication). Environmental damage such as this is irreparable. This is only 1 example of costs and consequences associated with nutria damage. As more data become available WS predicts the economic and ecological impact of this species will be substantially higher and greater.

Invasive Reptiles

At least 53 invasive species of reptiles and amphibians occur in the United States, including 30 in Florida and 12 in Hawaii (Pimental et al. 1999, McCoid and Kleberg 1995, Lafferty and Page 1997). Invasive amphibian data are not provided in this paper.

The number of requests for assistance for damages caused by invasive reptiles was small compared to invasive birds and mammals. The primary invasive reptile species reported in the MIS data was the brown treesnake. Requests for assistance came from Hawaii and Guam (Table 1). Requests for assistance with the monitor lizard (*Varanus indicus*) only originated from Guam. Due to the low frequency of requests, all other species of invasive reptiles were grouped into the category of exotic reptiles. Requests for assistance for control of exotic reptiles came from 10 states and 2 territories.

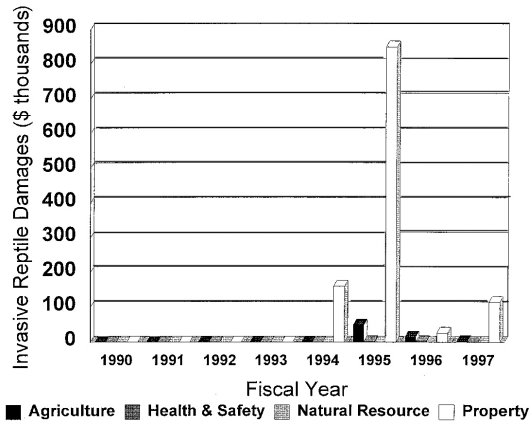

Fig. 6. The amount of invasive reptile-caused damages reported to Wildlife Services during the period of Fiscal Years 1990-1997.

Invasive reptiles accounted for only US$400 (FY 1995) in damage to natural resources throughout the period of FY 1990-1997 (Fig. 6). No human health and safety damage was attributable to invasive reptiles from FY 1990 to FY 1994. For the period FY 1995 through FY 1997, human health and safety damage amounted to <US$4,000. For FY 1990, 1992, and 1993, no monetary agriculture losses were attributed to invasive reptiles. Agricultural damage peaked in FY 1995 at US$49,755 and had a low of US$10 in FY 1991. Monetary losses to property by invasive reptiles occurred every FY except 1990 and 1993. Monetary losses to property peaked in FY 1995 at US$850,000. Invasive brown treesnakes accounted for 99.9% of damages reported to WS (US$1,225,812) out of the US$1,226,717 reported for all invasive reptiles. Brown treesnake damage averaged US$153,226 and had a median of US$21,802 per year.

Despite the low recorded monetary loss attributable to the brown treesnake, its impact has been considerable. The brown treesnake was accidentally introduced to Guam during the late 1940s. Since the 1940s, the brown treesnake has eliminated all breeding populations of seabirds on the island of Guam, caused the extinction of 10 of 13 species of endemic forest birds (the remaining 3 are endangered), and caused the extinction of 2 of 3 native mammals and 6 endemic lizards (Rodda et al. 1998). In addition to environmental damage, the brown treesnake also causes property damage (1,400 power outages between 1978 to 1996) (Fritts and Chiszar 1999), livestock losses (Fritts and McCoid 1991), and impacts human health and safety (Fritts and McCoid 1999). It is estimated that the cost of brown treesnake-related power outages is conservatively US$1 million per year and the cost of medical treatment of snake bites is US$25,000 per year (Pimental et al. 1999). Reported damage to resources caused by brown treesnakes for the period FY 1994 to FY 1997 was US$1,225,812. WS did not begin its management

of invasive brown treesnakes until FY 1994 on Guam, consequently the damages recorded were low. Overall, the amount of damage attributed to the invasive brown treesnake was minimal when considering the irreplaceable loss of species on Guam and the continuing threat to existing species.

CONCLUSIONS

Wildlife Services MIS findings indicate that invasive vertebrate species are a pervasive problem throughout the United States and its territories. WS data shows that every geographic area has a minimum of 3 species of invasive wildlife, with as many as 35 in Hawaii. The occurrences in Hawaii are classic examples of the devastation introduced species can cause. The true picture of the harm caused by invasive species cannot be fully appreciated until additional research is conducted and better models are developed to determine the full amount of damage caused by individual invasive species and groups of invasive species. Pimental et al. (1999) estimated that the >50,000 invasive species contribute to more than US$138 billion per year in damages. We believe this to be a conservative estimate, considering that Pimental et al. (1999) did not account for the invasive species damages reported to WS and other researchers at this symposium. He also underestimated species populations such as invasive swine. WS predicts that number of invasive species in the United States will continue to escalate due to smuggling, species escapes from private and public holdings, and minimal border inspections. Consequently, the United States has become not only the melting pot for humans, but the melting pot for invasive species. In essence, the United States and its territories are the perfect classroom to study the impacts of invasive species.

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